EVASIVE BEHAVIOR OF EASTERN TROPICAL PACIFIC DOLPHINS RELATIVE TO EFFORT BY THE TUNA PURSE-SEINE FISHERY

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ABSTRACT

The behavior of five stocks of four species of eastern tropical Pacific (ETP) dolphins, offshore spotted (*Stenella attenuata attenuata*), eastern spinner (*Stenella longirostris orientalis*), coastal spotted (*Stenella attenuata graffmani*), short-beaked common (*Delphinus delphis*), and striped (*Stenella coeruleoalba*), were analyzed relative to tuna purse-seine fishery effort. Behavioral data was collected for 1,218 sightings during Southwest Fisheries Science Center (SWFSC) research cruises in the ETP in 1998 and 1999. Using Principal Components Analysis (PCA) and Discriminant Function Analysis (DFA), we created two reaction indices (RIs) based on five discrete field-recorded behaviors that indicated a reaction to the research vessel. These field-recorded behaviors included approaching the research vessel, bow-riding, running, low swimming, and school splitting. Fishing effort data were supplied by the Inter-American Tropical Tuna Commission (IATTC). For each dolphin sighting, effort was defined as the number of sets made by the tuna purse-seine fishery within a given number of days and distance away from the sighting. Fifty-six effort "windows" ranging from 10 – 70 days and 30 – 300nm were used in the analysis. The number of sets per window ranged from 0-576. We asked the following three questions: (1) Can "reaction to the research vessel" be defined by a combination of discretely coded behaviors? (2) What is the relationship between dolphin reaction or any of the component behaviors and fishing effort? (3) If there is a relationship between dolphin behavior and effort, can behavior be used as a proxy of population level effects of the fishery?

The PCA identified a major principal component, which we defined as a "reaction index," that accounted for 35 – 56% (depending on stock) of the variance in the behavioral data (RI-PCA). In effort windows of greater distances and greater number of days, we found a significant positive correlation between RI-PCA and fishing effort for offshore spotted dolphins and eastern spinners (the species primarily targeted by the tuna purse seine fishery). This correlation was confirmed by a nonparametric test in which sightings classified by the DFA as having a negative reaction to the boat were associated with significantly more effort (difference in medians of 1 to 61 sets, depending on the effort window chosen). No significant correlation was found for any effort window for coastal spotted, short-beaked common dolphins, or striped dolphins, stocks that experience less involvement with the fishery. Logistic regressions fit to RI-PCA and fishing effort were significant for offshore spotted and eastern spinner dolphins, but non-significant for the non/less-targeted stocks. These findings suggest a causal link between fishing effort and the behavior of pelagic dolphins: targeted species have a greater tendency to exhibit behaviors associated with ship avoidance and evasion.

INTRODUCTION

The tuna fishery in the eastern tropical Pacific Ocean (ETP) sets 7,000-10,000 purse seines per year on schools of dolphins to capture the associated yellowfin tuna, (*Thunnus albacares;* IATTC 2000). When "fishing on dolphins," the set begins once the school is sighted and approached by the seiner. The latter may last from minutes to hours depending on distance and activity (National Research Council 1992). When in range,

four to six speedboats are lowered, beginning the chase. The speedboats herd the dolphins and the associated tuna into a tight group that can then be encircled by the net. Once the tuna have been captured ("pursed") in the lower section of the net, the encircled dolphins are released during the "backdown" procedure (Barham *et al.*, 1977).

It is conventional wisdom among observers familiar with dolphin behavior in the ETP that both the dolphins and the purse seiners have changed their behavior in relation to one another. Results from a number of studies suggest that dolphins have learned from their experience with nets and fishing vessels (Norris *et al.*, 1978; Holts *et al.*, 1979; Allen *et al.*, 1980; Pryor & Kang, 1980; Schramm Urrutia, 1997; Heckel *et al.*, 2000). Dolphins typically avoid any vessel sounding similar to a tuna seiner and some schools, in some areas, have apparently developed evasive behaviors that make capture difficult. For example, offshore spotted dolphin schools "explode" or disperse such that the approaching seiner and/or speedboats are left with such a small number of dolphins and tuna that the set is aborted (Allen *et al.*, 1980). This behavior earned certain dolphins the name "the untouchables" by the seiners (Pryor & Norris 1978) because the animals were, and still are, capable of completely evading the seining operation before the net has been set (Heckel *et al.*, 2000). Offshore spotted dolphins are also known to lie low in the water with nearly imperceptible movement, as if hiding from the seiner and speedboat. The animals then "blow through," or rapidly swim out of the containment circle formed by the wakes of the seiner and the speedboats, past the bow of the seiner, escaping capture (Holts *et al.*, 1979; Allen *et al.*, 1980). As these behaviors are commonly known to occur in areas of intensive fishing effort, they are indicative of learning and experience with nets and fishing vessels. Moreover, they are likely to spread and change, as do the methods of the seiners that chase them, in a classic illustration of co-evolution between predator and prey.

The behavioral response to vessels of eastern tropical Pacific dolphins has been previously studied in two contexts: (1) in an effort aimed at reducing mortality in the nets, and (2) to evaluate the effect on shipboard censusing of dolphins. Based on observations during purse seine operations, Norris *et al.* (1978) made the first ethogram for spotted dolphins *(Stenella attenuata)* and spinner dolphins (*Stenella longirostris)* during chase and set. Focusing on behavior in the net, Pryor & Kang (1980) interpreted many of their findings as an adaptive learned response to encirclement before release. Holts *et al.* (1979) and Allen *et al.* (1980) also studied dolphin behavior during fishing operations and described various maneuvers by which dolphins evaded capture during the chase prior to the setting of the net or after the net was set.

Three studies have been based on records from tuna vessel observers. Stuntz and Perrin (1979) note that dolphins (*Stenella spp*.) are more difficult to catch in areas of intense fishing effort and concluded that the dolphins learned to evade encirclement. More recently, Heckel *et al.* (2000) found significant geographic patterning to the evasive behavior of offshore spotted (*Stenella attenuata*) and eastern spinner dolphins (*Stenella longirostris orientalis*) which they suggested was related to fishery effort. They also noted different evasive strategies of the two stocks. Schramm Urrutia (1997) correlated the activity level of chased and captured dolphins to fishery effort, focusing primarily on activity during encirclement.

The line transect methods used to census dolphins assume that animals do not react to the research vessel before they are sighted by shipboard observers. This

assumption was tested, and found to be accurate, by three studies using helicopters deployed from survey vessels. Although there is evidence of some movement at large distances, these studies found that most dolphin schools were detected before they reacted to the survey vessel (Au and Perryman 1982; Hewitt 1985; Brandon *et al*. 2002).

Here, our interest in dolphin behavior is to assess the effect of the fishery by testing the relationship of dolphin response to a research vessel with recent fishery effort. We quantify behaviors recorded by observers during ETP research cruises conducted by the Southwest Fisheries Science Center in 1998 and 1999, and use multivariate statistical methods to examine the relationship between dolphin behavior and fishing effort. We focus on five stocks of four species: offshore spotted (*Stenella attenuata attenuata*), eastern spinner *(S. longirostris orientalis*), coastal spotted (*S. a. graffmani*), short-beaked common (*Delphinus delphis*) and striped (*S. coeruleoalba*) dolphins. Offshore spotted and eastern spinner dolphins are heavily involved in the tuna fishery. Coastal and common dolphins are involved but set upon much less frequently. Striped dolphins are generally not set upon (National Research Council 1992).

Annual mortality rates are commonly used to measure the effect of the fishery on dolphin populations (for mortality estimates see Annual Reports of the Inter-American Tropical Tuna Commission, La Jolla, CA). Currently, it is estimated that approximately one dolphin is killed for every three sets made, a significant reduction from historical levels (Hall & Lennert 1997). As Dizon *et al.* (2002) notes, even for the 99.9% released alive, few would argue that the experience is stress-free. For example, it has been suggested that mothers and calves attempting to avoid capture by running or splitting from the school may be more likely to be separated, potentially leading to the unobserved deaths of orphaned calves (Archer *et al.*, 2001; Edwards 2002). Simply the experience of repeated chase and capture may have effects on the social and behavioral ecology of schools. We discuss possible links between the observed behaviors and population level effects, which are important for future study.

METHODS

Study area and data collection

Survey Methods. The surveys in 1998 and 1999 were carried out aboard the NOAA ships *David Starr Jordan* and *McArthur*. The University of Rhode Island vessel *Endeavor* was also used in 1998. The primary objective of the cruises was to conduct line-transect surveys in order to estimate cetacean abundance in the area affected by the fishery and adjacent parts of the ETP (Fig. 1). Observers also wrote a narrative account of each sighting and filled out a sighting form detailing behavioral observations (Appendices 1 and 2, and see below). All ships are similar in length (52-57m) and observer eye height (10.4-10.7m). In each year, the ships were in the study area for approximately four months, from late July through the first week in December, with port stops every 3-4 weeks (Gerrodette & Forcada 2001).

Methods of collecting data followed standard protocols for line-transect surveys conducted by the Southwest Fisheries Science Center, SWFSC (Kinzey *et al.*, 2000). During daylight hours and in good weather, a visual search for cetaceans was conducted on the flying bridge of each vessel as the ship moved along the trackline at approximately 10 knots. While on duty, two observers, one on each side of the ship, scanned a 110-

degree wedge that started abeam of the vessel on their side and ending 10-degrees past the trackline on the opposite side of the bow with 25x pedestal-mounted "big eye" binoculars. A third observer searched by eye and with hand-held 7x binoculars, covering the area close to the trackline.

When marine mammals were sighted, observers recorded the distance, angle and reticle to the animals, as well as various other environmental variables, such as Beaufort state, presence of birds, etc. The observers identified the sighting to species or subspecies (if possible), estimated group size, and observed dolphin behavior. After the sighting was complete, the observer who made the initial sighting was responsible for filling out the sighting form (NOAA form 88-208, Appendix 2). Behavioral observations were compiled from all observers that saw the sighting and both a narrative and a series of behavioral questions were filled out.

Extraction of behavioral data from the sighting forms. Behavioral data were extracted from the narrative accounts of each sighting, and coded using standardized terms (Appendix 1). The standardized definitions were included in a new, expanded sighting form (the back side of NOAA Form 88-208, see Appendix 2), which was first used on the 1999 cruise. Prior to the cruises, all observers attended a training course detailing the observation and recording of behavioral data (summarized in Dolphin Behavior in the ETP (Appendix 3) which has subsequently evolved into the Guide to Behavioral Data Collection for Observers). We examined all sightings that were initially made on-effort of offshore spotted, eastern spinner, coastal spotted, short-beaked common, and striped dolphins during 1998 and 1999.

In order to quantify the sighting form information we created a database with 35 fields (Table 1). The database was modified slightly to improve clarity from 1998 to 1999, based on observer suggestions. The first 16 fields of each data record were part of the standard information collected with each sighting. Fields 17-35 involve the newly standardized behavioral terms, and were extracted from the narrative accounts of each sighting (1998), or were obtained directly from the sighting form (1999). The Southwest Fisheries Science Center species codes used in this study are given in Table 2.

Five discretely coded behaviors were used to give an overall picture of a school's reaction to the vessel: approaching the boat, bow-riding, running from the boat, low swimming, and school splitting (see Appendix 1 for definitions of specific behaviors). These behaviors were used in the principal components analysis and to train the discriminate function (see below in Statistical Methods).

To summarize the data from the field, observers also subjectively categorize each sighting as "evasive," "non-evasive," "both," "cannot be determined," "other," or "no record" (Field 34, Table 1) based not only on the presence or absence of the above behaviors but also upon their experience and judgment, using the following definitions. These subjective classifications of the observers were subsequently used as *a-priori* groups in the discriminant function (see below in Statistical Methods).

Evasive. An evasive sighting was defined as one that included one or more of the following behaviors: running, school splitting, and low-swimming, or other behaviors that might be associated with evasion, such as, but not limited to, running toward rain squalls, frequent changes of direction, or hiding on the back side of swells.

Non-evasive. A non-evasive sighting was defined as one in which the dolphins approached the boat, or were observed bow-riding or wake-riding.

Both. A sighting that included behaviors from both of the previous two categories was considered to be both evasive and non-evasive. For example, the dolphins may approach the vessel, turn to run, and then split during the course of one sighting.

Cannot be determined. In their best determination, the observer felt they were unable to make a valid call.

No record. When all behavior relative to the vessel (Fields 26-33) was unknown because of missing information, it was recorded as "no record."

Estimating Fishing Effort

We estimated the experience that a dolphin has had with purse seining in the ETP by accumulating the number of sets that occurred prior to encountering the sighting within a circumscribed area and time following the methods described by Dizon *et al.* (2002). A custom written Visual Basic 6 program was provided to the IATTC for application to their data sets. For each sighting, the program steps through extractions of the observer and skipper databases, which contained a time-ordered array of sets made by the U.S. and international yellowfin tuna purse seine fleet. Our program summed sets occurring within 30, 60, 90, 120, 150, 180, 240, and 300 nautical miles centered on the sighting location and occurring 10, 20, 30, 40, 50, 60, and 70 days prior to sampling.

Statistical Analyses

In this analysis, only sightings with the following five stocks were used: offshore spotted dolphins (*Stenella attenuata attenuata*), coastal spotted dolphins (*Stenella attenuata graffmani*), eastern spinner dolphins (*Stenella longirostris orientalis*), striped dolphins (*Stenella coeruleoalba*), and short-beaked common (*Delphinus delphis)* dolphins. The presence of a stock in a sighting, whether from a pure or mixed school, contributed behavioral data for that stock. To avoid small sample sizes, sightings of pure schools were not analyzed separately and northeastern and western-southern stocks of offshore spotted dolphins were combined. The data from mixed school sightings (comprised predominantly of offshore spotted and eastern spinner dolphins) were applied to both the stocks. Sample sizes for each stock are summarized in Table 3. Unless otherwise noted, only sightings in which information was available on all of the five discretely coded field variables were used in the analyses.

For each sighting, effort was defined as the number of sets made by the tuna purse-seine fishery within a given number of days and distance away from the sighting. Fifty-six effort "windows" ranging from 10 – 70 days and 30 – 300nm were used in the analysis. The number of sets per window ranged from 0-576.

Figure 2 shows a flow chart summarizing the data analyses conducted in this study. In all cases, we began with the five discretely-coded field behaviors: approach, bow-ride, run, low swim, and school splitting. Our first objective was to use a Principal Components Analysis (PCA) to summarize the information in the five behaviors into a single variable that represented the reaction to the research vessel. In the first component generated by the PCA, the variables of approach and bow-ride were consistently of opposite sign to run, school splitting, and low swim (except in the case of coastal spotters). Thus we defined this component as a "reaction index" (RI-PCA). RI-PCA was

then rescaled so the minimum value was 0 and the maximum was 1. The first component accounted for 35 – 56% (depending on stock) of the variance (see Results). The remaining four components accounted for less variance than a single variable for most stocks and thus were not used.

In order to generate a discrete reaction index, we used a Discriminant Function Analysis (DFA) to classify sightings based on their scores on the five discretely coded field variables, grouped by the observers' subjective score for the entire sighting *(evasive, nonevasive, both, unknown* or *other)*. Only sightings initially scored as *evasive* or *non-evasive* were used as *a-priori* groups in the discriminant function. The resultant function was then used to reclassify all sightings with data available, including those initially scored as *both, unknown,* or *other* by the observer. We labeled this second, discrete reaction index, "RI-DFA".

Our next objective was to examine the relationship between reaction index and fishing effort. For each of the following tests (numbers refer to the flowchart in Fig 2), results are reported for each of the 56 effort windows. Results with $p \leq 0.05$ are considered to be statistically significant.

(1) We calculated the Pearson product-moment correlation between RI-PCA and fishery effort, with statistical significance determined by Bonferroni probabilities.

(2) Because the distribution of fishing effort is not normally distributed, we used the non-parametric Mann-Whitney U test to examine differences between the median number of sets between "evasive" and "non-evasive" sightings. Sightings were grouped based on their RI-DFA score.

(3) We used the logistic regression,

$$RI\_PCA = \frac{1}{1 + e^{-a - (b*Effort)}}$$

 to model the relationship between RI and fishery effort. If the 95% Wald confidence interval for *b* did not include 0, the regression was considered significant. We present y-intercept values for each regression as they represent our best estimate of the expected response of dolphins not recently exposed to fishery effort.

Lastly, we were interested in the correlation between the observer's subjective classification of an entire sighting as *evasive* or *non-evasive* and their scores on the five discretely-coded behavioral variables. This was assessed by the number of correctly classified sightings in the DFA; higher classification scores indicating greater internal "consistency" in observer data recording.

Mapping

The behavioral reactions to the research vessel based on the observers' subjective score were summarized by stock and were plotted by geographic location using MapInfo Professional 4.0 (Fig. 3a-f). Records without sufficient data to determine evasive behavior were not included in the plots.

RESULTS

In total, 1,218 sightings were analyzed for five stocks of pelagic dolphins during 1998 and 1999 (Table 3). Of these, 483 had information available for all five of the

discretely coded behavioral variables and thus had sufficient data to be analyzed by the PCA and DFA. To get an overall picture of the data, the reaction to the research vessel, as defined by the subjective score of the observers, is plotted by stock in Figure 3. The reaction varies among stocks and for some stocks, among geographic locations. The overall percentage of evasive behavior for each stock, in descending order, is: striped dolphins, 60.0%; offshore spotted dolphins, 46.9%; eastern spinner dolphins, 42.8%; short-beaked common dolphins, 32.5%; and coastal spotted dolphins, 2.0%.

      The first component generated by the PCA accounted for 35 – 56% (depending on stock) of the variance in the behavioral data. The loadings of variables coding for approaching the vessel and bow-riding were consistently of opposite sign to those coding for running, school splitting, and low swimming behaviors. Except for coastal spotters, approaching the vessel was consistently slightly more important than bow-riding in defining a positive reaction to the boat, while running was more important than low swimming or splitting in defining a negative reaction. The first component was independently rescaled for each stock to have a minimum of 0 and a maximum of 1, which we termed a reaction index (RI-PCA), where 0 signified the most positive reaction to the vessel (the school approached and bow-rode, but never exhibited running, splitting, or low swimming behavior), and 1, the most negative reaction (the school, ran, split, and exhibited low swimming, but never approached nor bow-rode).

      In effort windows of greater distances and greater number of days, we found a significant positive correlation between RI-PCA and fishing effort for offshore spotted dolphins and eastern spinners (the species primarily targeted by the tuna purse seine fishery; Table 4). This correlation was confirmed by the nonparametric Mann-Whitney U test in which sightings classified by the DFA as having a negative reaction to the boat were associated with significantly more effort (difference in medians of 1 to 61 sets, depending on the effort window chosen; Table 5). No significant correlation was found for any effort window for coastal spotted, short-beaked common dolphins or striped dolphins, stocks that experience no/less involvement with the fishery.

      Logistic regressions fit to RI-PCA and fishing effort were significant for offshore spotted and eastern spinner dolphins, but non-significant for non/less-targeted stocks (Table 6 and Figure 4). The y-intercept values for significant regressions for offshore spotted and eastern spinner dolphins range from 0.34 to 0.64. Striped dolphins show a flat, non-significant correlation between reaction and fishery effort. The high (0.9) y-intercept values for RI-PCA (although non-significant) suggest that this species has a consistently high evasion response to the research vessel. Offshore spotted and eastern spinners show a significant positive relationship between reaction and fishery effort. The intermediate y-intercept values (approximately 0.6 and 0.4, respectively) show that these stocks have an approximately equal chance of reacting to the research vessel by swimming away or coming towards when they have not experienced recent fishing activity. However, as fishing effort increases, so does the probability of observing an evasive response. Coastal spotted dolphins also show a flat, non-significant relationship between reaction and fishing effort. The low y-intercept value (0.1) reflects the fact that these animals frequently approach the research vessel and bow-ride.

      Using the five behavioral variables, the DFA was able to correctly classify greater than 95% of sightings for all stocks except coastal spotted dolphins as "evasive" or "non-evasive" (Table 7). This indicates that observers are fairly consistent in their recording of

the five behavioral variables and their subjective scoring of the overall behavior of the school.

DISCUSSION

Defining "Reaction to Vessel"

Using PCA, we examined the information content in the five discretely-coded behavioral variables (approaching vessel, bow-riding, running, low swimming, and school splitting). Our results show that a majority of the information can be summarized by a single continuous reaction index (RI-PCA). The relative magnitudes of the variable loadings indicate that approaching the vessel and running are the two most important positive and negative behaviors in the index, but in analyses of the other stocks, the remaining three variables also had loadings often greater than 0.6 (data not shown). In this study, we did not thoroughly examine the differences in variable loading between stocks. Although the behaviors are correlated, it is possible that two stocks with similar reaction indices will exhibit different combinations of behaviors that may be evident in further study of the component variables. The high discriminant function scores suggest that observers are quite consistent between their gross estimation of school "evasiveness" and their recording of discrete behaviors.

Caveats

It is important for us to emphasize that the behaviors we examined during this study were not recorded from a fishing vessel or a platform in any way designed to mimic a fishing vessel. Additionally, differences between the research vessels and fishing vessels may influence some of the behaviors we recorded. Our observations begin when the school is detected and usually last only as long as is necessary to make reliable abundance estimates and stock identifications. This period might be compared to the dolphins' behavior "before chase" during fishing operations (before the speed boats are lowered; following Heckel *et al.*, 2000). Thus, we recognize that we are only examining a small range of the possible behaviors that may be exhibited during a purse-seine set. However, we are not attempting to directly examine the relationship of dolphin behavior to fishing vessels, but rather that of behavior to recent fishery effort.

In addition to different levels of experience with the tuna fishery, we recognize that a variety of other factors may contribute to the differences in behavior we recorded among stocks. These could include, but are not limited to, differing experience with other types of vessels (e.g., cargo, pleasure craft, etc.), differences in social structure, or variation in their ecological or physical environment.

Inherent in a study such as this which relies on behavioral observations taken at sea are limitations and potential biases which may affect the results. Simply put, observers are unable to record behaviors that occur outside of their range of view. Moreover, they may have their attention directed away from behaviors within their range of view, or may have behaviors obscured by weather and sea conditions. Although observers received the same level of training prior to each survey cruise, they have

varying degrees of familiarity with the region and stocks. This could potentially influence the way they record behaviors seen.

Relationship between dolphin behavior and fishery effort

In effort windows of greater distances and greater number of days, we found a significant positive correlation between RI-PCA and fishing effort for offshore spotted dolphins and eastern spinners, the species primarily targeted by the tuna purse seine fishery. This correlation was confirmed by a nonparametric test in which sightings classified by the DFA as having a negative reaction to the boat were associated with significantly more fishing effort. No statistically significant results were found for any effort window for coastal spotted, short-beaked common dolphins, or striped dolphins, stocks that experience less involvement with the fishery.

The results of the logistic regressions suggest a causal link between fishing effort and the behavior of pelagic dolphins: targeted stocks have a greater tendency to exhibit behaviors associated with ship avoidance and evasion. The y-intercept values indicate that the different stocks generally exhibit different reactions to the research vessel. Coastal spotted dolphins, and to a lesser extent, short-beaked common dolphins, tend to be attracted to the research vessel, and are frequent bow-riders, while striped dolphins tend to run from research vessels across their range. Offshore spotted and eastern spinner dolphins have an approximately even chance of avoiding or approaching the research vessel if they have not had a recent experience with the tuna purse seine fishery.

It is important to note that while the behaviors described here may be learned behavioral responses which enable dolphins to successfully evade purse seiners, there may be other population level implications. One of the primary evasive behaviors that we identified was running. The physical exertion involved in running certainly places higher energetic loads on individuals (Edwards 2002), which in turn are likely to affect any number of behaviors, including foraging and reproduction. Stocks or schools exhibiting evasive behaviors may be more likely to show elevated stress markers, linking this study with those of Dizon *et al.* (2002) and Southern *et al.* (2002). School splitting is a particularly interesting behavior because it may lead to the disruption of social bonds and have consequences for the members, such as the separation of mothers and calves, or the disruption of lactation (Archer *et al.*, 2001). We suspect the extent of this disruption is highly dependent on the duration of the chase and demographics of the school. The consequences, however, may include decreased reproductive rates, increased rates of juvenile mortality, or increased predation.

Future Research

Future research should be focused on adding more raw data to the current study, primarily behavioral records and associated fishing effort from the MOPS (1986-1999) and STAR 2000 abundance cruises. Where possible, we would also like to include any available IATTC behavioral data. Research vessel data relates to the period of time "before chase" (the release of speedboats) during the seining operation. The IATTC has behavioral data on dolphins before chase, during chase, and in the net. Heckel *et al.* (2000) analyzed the behavioral data but was unable to correlate geographic differences in

behavior with fishing effort. We would like to combine data sets, compare the "before chase" data, and look at the correlation between behavior and fishing effort at these other times.

With a database of sufficient size, we feel it is important to analyze mixed and pure schools separately as Heckel *et al.* (2001) indicate that spotted dolphin behavior is influenced by the proportion of spinner dolphins in mixed schools. We would also like to examine temporal and spatial differences within each stock. A more detailed spatial and temporal analysis will enable us to test more precisely for fishery effects.

A more detailed analysis of the available data fields is also warranted. We are interested in examining behavior as a function of school size and composition, especially the presence of calves. It is possible that schools with large numbers of calves may behave differently (S. Mesnick pers. ob., L. Morse, pers. comm.). It is also important to conduct a more detailed univariate analysis of the behavioral data. "School splitting" is especially interesting because it may relate to the separation of mother and calves. "Running" may link directly with studies of physical exertion, etc. Not only might this elucidate the relationship between learned adaptive responses to the fishery but this type of analysis may also enable us to track the learning and spread of particular behaviors through the region. In addition to these data, we should investigate the inclusion of other behaviors (such as running towards rain squalls and hiding in the back of swells) that have been identified as learned evasive responses by other researchers.

Valuable information may be obtained by working with fisherman to determine fishing methods per area/stock. It is common knowledge that the purse seining operation has also changed their methods to exploit particular behaviors of the various stocks and this can be examined both temporally and spatially.

Finally, our analyses should be combined with other data collected such as stress studies, energetics, and life history. Examinations of photogrammetry data may help elucidate the temporal and spatial occurrences of various behaviors and how the shape and cohesion of a school changes during the chase. The photogrammetry group collected behavioral data in 2001, and this has yet to be analyzed with these questions in mind.

ACKNOWLEDGEMENTS

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Table 1. 1999 database fields and codes. (* = add all codes that apply and record sum.)

Field	Description	Code / value
1	Date	Date of sighting
2	Time	Time of sighting (local)
3	Sighting number	Sequential sighting number
4	Observer ID	Number of observer who made the initial sighting
5	Location	Latitude and longitude
6	Sea state	Beaufort scale
7	Species	Codes in Table 2
8	School size	Mean of each observer's best estimate
9	Angle at sighting (degrees)	999 = no record
10	Reticle at sighting	999 = no record
11	Initial distance (nm)	999 = no record
12	Initial speed of school (knots)	999 = no record
13	Direction relative to bow (degrees)	999 = no record
14	Closest distance (nm)	999 = no record
15	Associated animals *	1 = marine mammal, 2 = birds, 4 = tuna, 8 = no associations, 999 = no record
16	Calibration school	1 = yes, 2 = no, 999 = no record
17	Individual behavior *	1 = aerial activity, 2 = lob tailing, 4 = porpoising, 999 = no record
18	When first observed, were animals reacting to the vessel?	1 = yes, 2 = no, 3 = unknown, 100 = other, 999 = no record
19	Initial group behavior *	1 = fast traveling, 2 = moderate traveling, 4=slow traveling, 8 = milling, 16 = associated swimming, 32 = unknown, 100 = other, 999 = no record
20	Did the behavior change during the observation?	1 = yes, 2 = no, 3 = unknown, 100 = other, 999 = no record
21	Subsequent group behavior *	1 = fast traveling, 2 = moderate traveling, 4=slow traveling, 8 = milling, 16 = associated swimming, 32 = bow-riding, 64 = approach, 100 = other, 128 = not applicable, 129 = unknown, 999 = no record
22	Degree of aggregation	1 = tightly aggregated, 2 = loosely aggregated, 3 = unknown, 100 = other, 999 = no record
23	Spacing	1 = uniform, 2 = clumped, 3 = unknown, 100 = other, 999 = no record
24	Did distribution change during sighting?	1 = yes, 2 = no, 999 = no record
25	Presence of calves from form	1 = yes, 2 = no, 3 = unknown, 100 = other, 999 = no record
26	Travel towards the boat (approach)	1 = yes, 2 = no, 3 = unknown, 100 = other, 999 = no record
27	Bow riding	1 = yes, 2 = no, 3 = unknown, 100 = other, 999 = no record

Table 1, continued. 1999 database fields and codes. (* = add all codes that apply and record sum.)

Field   Description   **Code / value**

Field	Description	Code / value
28	Travel away from the boat (running)	1 = yes, 2 = no, 3 = unknown, 100 = other, 999 = no record
29	Low swimming	1 = yes, 2 = no, 3 = unknown, 100 = other, 999 = no record
30	Group splits?	1 = yes, 2 = no, 3 = unknown, 100 = other, 999 = no record
31	If split, did the subgroups move off in different directions?	1 = yes, 2 = no, 3 = unknown, 4 = not applicable, 100 = other, 999 = no record
32	Subgroup composition	1 = single species, 2 = mixed-species, 3 = unknown 4 = not applicable, 100 = other, 999 = no record
33	Other evasive behavior	1 = yes, 2 = no, 999 = no record
34	Relative to the research vessel, was this school:	1 = evasive, 2 = non-evasive, 3 = both evasive and non-evasive, 4 = cannot be determined, 100 = other, 999 = no record
35	Comments	Any behavior that does not fit into one of the above fields

Table 2. Dolphin species and stocks whose behavior was recorded and compared in the present study. Species codes are those used by the Southwest Fisheries Science Center.

Species code	Scientific name	Common name
2	*Stenella attenuata attenuata*	Offshore spotted dolphin
3	*Stenella longirostris*, unid. subsp.	Unidentified spinner dolphin
5	*Delphinus* sp.	Unidentified common dolphin
6	*Stenella attenuata graffmani*	Coastal spotted dolphin
10	*Stenella longirostris orientalis*	Eastern spinner dolphin
13	*Stenella coeruleoalba*	Striped dolphin
17	*Delphinus delphis*	Short-beaked common dolphin
90	*Stenella attenuata*, unid. subsp.	Unidentified spotted dolphin

Table 3. Sample sizes.

Stock	Number of sightings with the following stocks present (1998 and 1999 SPAM and STAR cruises)	Number of sightings with the following stocks present that were used in analysis (sightings with data available for all five discrete field-coded variables)
Offshore spotted	471	207
Coastal spotted	75	24
Eastern spinner	229	112
Striped	397	145
Short-beaked common	255	104

Table 4. p-values of the Pearson product-moment correlations of RI-PCA and fishing effort. Statistically significant values (p <= 0.05) are shown in yellow.

TARGETED SPECIES

a. Offshore spotted dolphins.

Days \ Distance	30	60	90	120	150	180	240	300
10	-0.01	0.02	0.08	0.08	0.10	0.13	0.10	0.08
20	0.08	0.12	0.15	0.15	0.16	0.18	0.19	0.18
30	0.04	0.11	0.13	0.14	0.15	0.16	0.17	0.17
40	0.05	0.12	0.15	0.15	0.17	0.19	0.18	0.17
50	0.11	0.16	0.18	0.20	0.21	0.23	0.22	0.21
60	0.14	0.19	0.21	0.22	**0.24**	**0.25**	**0.25**	**0.24**
70	0.13	0.19	0.21	0.23	**0.25**	**0.26**	**0.25**	**0.25**

b. Eastern spinner dolphins.

Days \ Distance	30	60	90	120	150	180	240	300
10	0.04	0.18	0.26	0.27	**0.32**	**0.36**	**0.42**	**0.41**
20	0.12	0.27	**0.32**	**0.32**	**0.34**	**0.37**	**0.42**	**0.45**
30	0.10	0.26	**0.33**	**0.33**	**0.33**	**0.35**	**0.40**	**0.45**
40	0.13	0.29	**0.36**	**0.35**	**0.37**	**0.39**	**0.44**	**0.47**
50	0.23	**0.31**	**0.35**	**0.35**	**0.38**	**0.39**	**0.43**	**0.46**
60	0.23	0.30	**0.33**	**0.35**	**0.37**	**0.39**	**0.42**	**0.44**
70	0.23	0.29	**0.33**	**0.35**	**0.38**	**0.39**	**0.43**	**0.46**

LESS- / NON-TARGETED SPECIES

c. Coastal spotted dolphins.

Days \ Distance	30	60	90	120	150	180	240	300
10	-0.20	-0.21	-0.21	-0.21	-0.19	-0.20	-0.24	-0.24
20	-0.19	-0.24	-0.19	*N/A*	*N/A*	-0.38	-0.23	-0.30
30	-0.19	-0.21	-0.18	*N/A*	*N/A*	-0.35	-0.29	-0.36
40	-0.21	-0.23	-0.22	*N/A*	*N/A*	-0.35	-0.27	-0.34
50	-0.26	-0.25	-0.26	*N/A*	*N/A*	-0.40	-0.31	-0.38
60	-0.22	-0.19	-0.22	-0.33	-0.38	-0.42	-0.33	-0.39
70	-0.21	-0.13	-0.15	-0.27	-0.34	-0.39	-0.31	-0.35

d. Short-beaked common dolphins.

Days \ Distance	30	60	90	120	150	180	240	300
10	0.00	0.06	0.07	0.02	0.05	0.04	-0.02	0.06
20	0.08	0.15	0.10	*NS*	*NS*	-0.04	-0.08	0.01
30	0.07	0.08	-0.03	*NS*	*NS*	-0.07	-0.09	-0.01
40	0.01	0.04	-0.0	*NS*	*NS*	-0.08	-0.10	0.00
50	0.00	0.03	-0.0	*NS*	*NS*	-0.09	-0.09	0.00
60	-0.02	0.00	-0.06	-0.08	-0.07	-0.09	-0.09	-0.01
70	0.00	0.02	-0.05	-0.08	-0.06	-0.06	-0.06	0.02

e. Striped dolphins.

Days \ Distance	30	60	90	120	150	180	240	300
10	0.02	0.04	0.02	0.03	0.03	0.00	-0.06	-0.13
20	0.05	0.06	0.05	*NS*	*NS*	0.07	0.01	-0.04
30	0.06	0.08	0.10	*NS*	*NS*	0.11	0.04	0.00
40	0.08	0.10	0.1	*NS*	*NS*	0.12	0.04	0.01
50	0.09	0.11	0.1	*NS*	*NS*	0.12	0.07	0.04
60	0.09	0.11	0.13	0.13	0.14	0.13	0.08	0.06
70	0.09	0.11	0.13	0.13	0.14	0.13	0.08	0.06

Table 5. Difference between median number of sets for "evasive" and "non-evasive" sightings as classified by the discriminant function analysis. Comparisons with significant (p <= 0.05) Mann-Whitney U tests are shown in yellow.

TARGETED SPECIES

LESS- / NON-TARGETED SPECIES

a. Offshore spotted dolphins.

Days \ Distance	30	60	90	120	150	180	240	300
10	0	0	0	-1	-1	0	0.5	2
20	0	0	0	0	1	0.5	6.5	7.5
30	0	-1	0	0.5	-1	-3	3	11
40	0	-1	1	1.5	4	5	9	21.5
50	0	0	3	2.5	5.5	8	17.5	27
60	0	0	3	3	6	11	18.5	38.5
70	0	1	2	5	6	11	19.5	48

c. Coastal spotted dolphins.

N/A

b. Eastern spinner dolphins.

Days \ Distance	30	60	90	120	150	180	240	300
10	0	0	2	2	3	8	29	34.5
20	0	1	3	2	3	12	28.5	39
30	0	0.5	2	4	5	10	22.5	34.5
40	0	1	4	6.5	9.5	13	33.5	46
50	0	1	5.5	6	10	15	31.5	52
60	0	2	5.5	5.5	11	17	31.5	68.5
70	0	2	5.5	6.5	12	18.5	32	61

d. Short-beaked common dolphins.

Days \ Distance	30	60	90	120	150	180	240	300
10	0	0	0	0	0	0	3	6
20	0	0	0	1	3	13	12.5
30	0	0	3	5	25	32
40	0	0	1	5	14	31.5	37
50	0	0	1	10	15	41.5	46
60	0	0	1	4	10	21	44.5	58
70	0	0	1	6	11	23	57.5	79.5

NS

e. Striped dolphins.

Days \ Distance	30	60	90	120	150	180	240	300
10	0	0	0	-2	-4	-2	-1	-3
20	0	0	2	1	5	-0.5	-5.5
30	0	-1	4.5	6	10.5	12.5	5
40	0	0	2	3.5	8.5	2	-20.5
50	0	1	2	8.5	12	5	-3.5
60	0	-0.5	0	4.5	10	4	10.5	8
70	0	0	3	18	21	16.5	35.5	40

NS

Table 6. Y-intercepts for the logistic regression of RI-PCA and fishing effort. Significant regressions (see text) are shown in yellow.

TARGETED SPECIES

a. Offshore spotted dolphins.

				Distance				
Days	30	60	90	120	150	180	240	300
10	DNC	DNC	DNC	0.68	0.67	0.66	0.66	0.67
20	DNC	DNC	DNC	0.67	0.66	0.66	0.64	0.64
30	DNC	DNC	0.67	0.67	0.66	0.66	0.65	0.64
40	DNC	0.67	0.66	0.66	0.65	0.65	0.64	0.63
50	DNC	0.66	0.65	**0.64**	**0.63**	**0.63**	**0.62**	**0.61**
60	DNC	**0.65**	**0.64**	**0.63**	**0.63**	**0.62**	**0.61**	**0.60**
70	DNC	**0.65**	**0.64**	**0.63**	**0.62**	**0.61**	**0.60**	**0.60**

b. Eastern spinner dolphins.

				Distance				
Days	30	60	90	120	150	180	240	300
10	DNC	0.54	**0.52**	**0.51**	**0.49**	**0.47**	**0.42**	**0.40**
20	DNC	**0.50**	**0.49**	**0.49**	**0.49**	**0.48**	**0.43**	**0.40**
30	DNC	**0.51**	**0.49**	**0.49**	**0.49**	**0.48**	**0.44**	**0.39**
40	DNC	**0.50**	**0.48**	**0.48**	**0.47**	**0.46**	**0.41**	**0.37**
50	DNC	**0.50**	**0.48**	**0.48**	**0.46**	**0.45**	**0.40**	**0.36**
60	DNC	**0.50**	**0.48**	**0.47**	**0.46**	**0.45**	**0.40**	**0.36**
70	DNC	**0.50**	**0.48**	**0.47**	**0.45**	**0.44**	**0.38**	**0.34**

LESS- / NON-TARGETED SPECIES

c. Coastal spotted dolphins.

				Distance				
Days	30	60	90	120	150	180	240	300
10	0.08	0.08	0.08	0.08	DNC	0.08	DNC	DNC
20	0.08	0.09	0.0	N/A	08	DNC	0.77	DNC
30	0.07	0.07	0.		8	0.10	0.07	DNC
40	0.07	0.07	0.		1	DNC	0.07	DNC
50	0.09	0.08	0.		9	0.44	0.10	DNC
60	0.07	0.07	0.07	0.10	0.46	0.18	DNC	DNC
70	0.07	0.07	0.07	0.10	0.34	0.17	DNC	DNC

d. Short-beaked common dolphins

				Distance				
Days	30	60	90	120	150	180	240	300
10	DNC	DNC	DNC	DNC	0.60	0.60	0.62	0.60
20	DNC	DNC	DNC	NS	1	0.62	0.63	0.61
30	DNC	DNC	0.6	2	62	0.63	0.64	0.61
40	DNC	DNC	0.	63	3	0.63	0.64	0.61
50	DNC	DNC	0.	63	63	0.63	0.64	0.61
60	DNC	0.61	0.62	0.63	0.63	0.63	0.64	0.61
70	DNC	0.61	0.62	0.63	0.63	0.63	0.63	0.61

e. Striped dolphins.

				Distance				
Days	30	60	90	120	150	180	240	300
10	DNC	DNC	DNC	DNC	DNC	DNC	0.91	0.92
20	DNC	DNC	DN	NS	C	DNC	0.90	0.91
30	DNC	DNC	DN		NC	0.89	0.90	0.90
40	DNC	DNC	DN	89	9	0.89	0.90	0.90
50	DNC	DNC	D	89	89	0.89	0.90	0.90
60	DNC	DNC	DNC	0.89	0.89	0.89	0.89	0.89
70	DNC	DNC	DNC	0.88	0.88	0.88	0.89	0.89

Table 7. Percentage of sightings correctly classified as "evasive" or "non-evasive" based on a discriminant function using the discrete behaviors of approach, bow-ride, run, split, and low swim. Groups a-priori assigned from observer's subjective score of sighting.

Species	% correctly classified	p-value	n
Offshore spotted	98%	0.0000	168
Eastern spinner	97%	0.0000	87
Coastal spotted	N/A	N/A	N/A
Short-beaked common	95%	0.0000	76
Striped	98%	0.0000	130

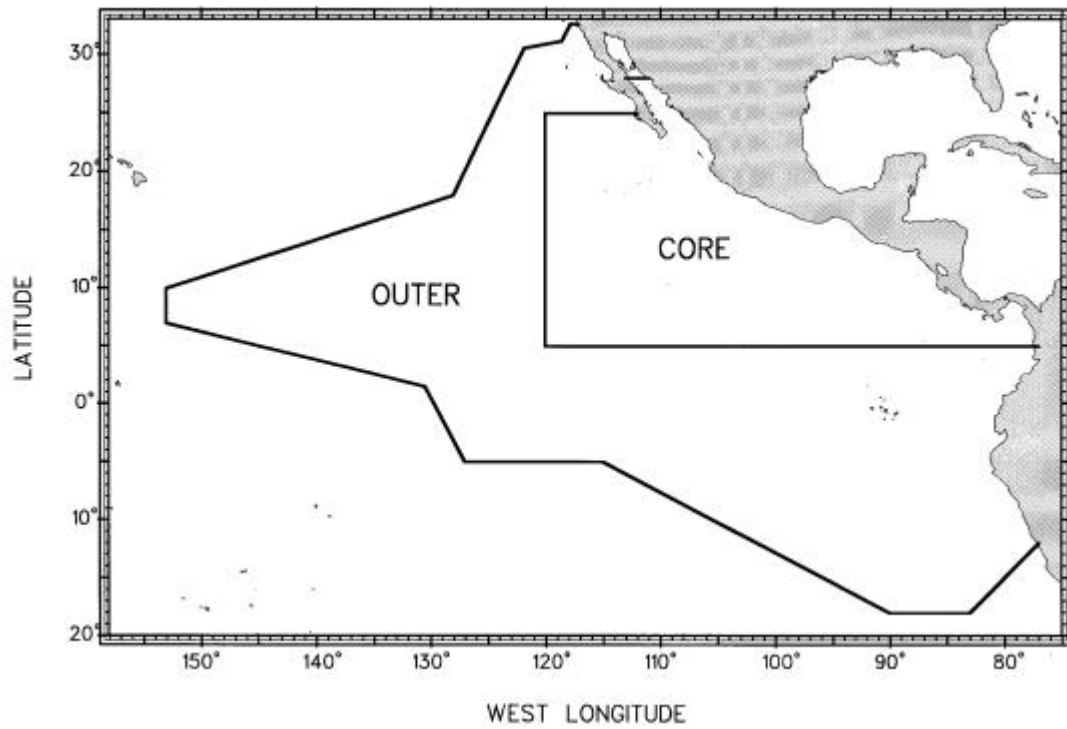Figure 1. Map of the eastern tropical Pacific delimiting the outer and core areas of the tuna fishery.

Figure 2. Data analysis flow chart.

Analysis   **Reaction Index**   **Statistical Test**

Rescale first component to have a
minimum of 0 and a maximum of 1.

**Discretely coded
behavioral variables**

PCA ⟹ **RI-PCA**

1. **Correlation with effort**

3. **Logistic regression with effort**

**Approach
Bow-ride
Run
Split
Low swim**

DFA ⟹ **RI-DFA**

2. **Mann-Whitney U test with effort**

3. **Logistic regression with effort**

Use discriminant functions to reclassify
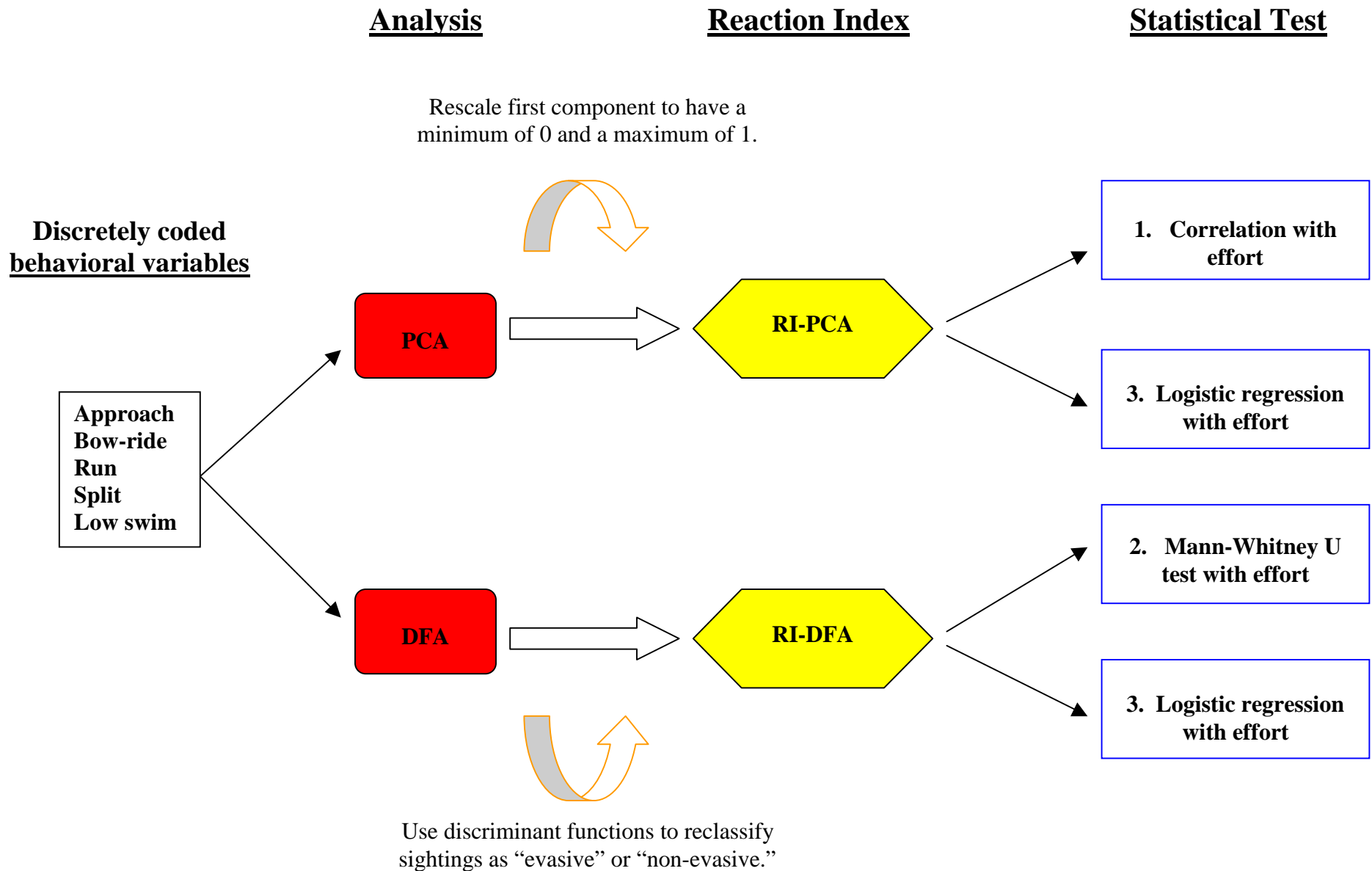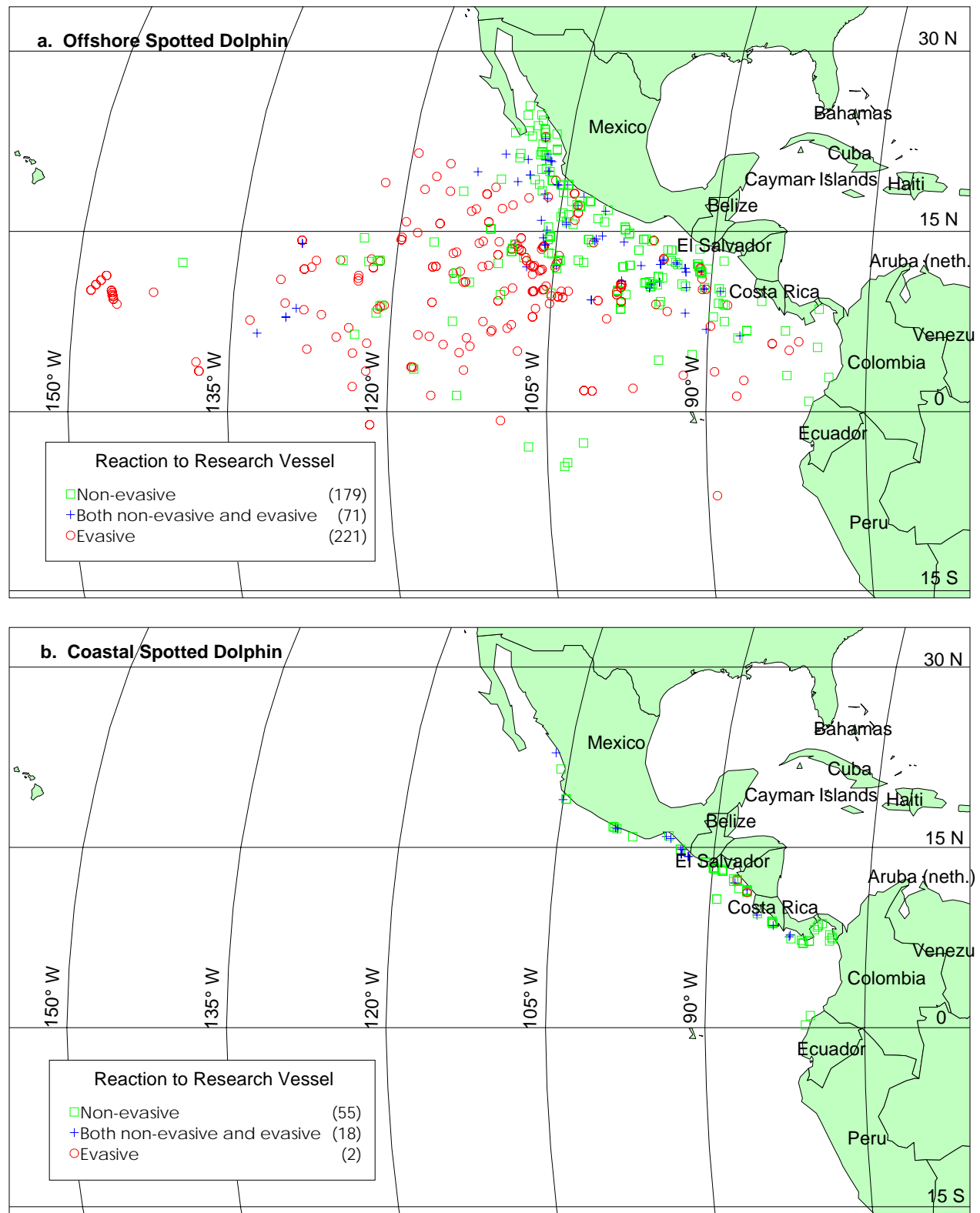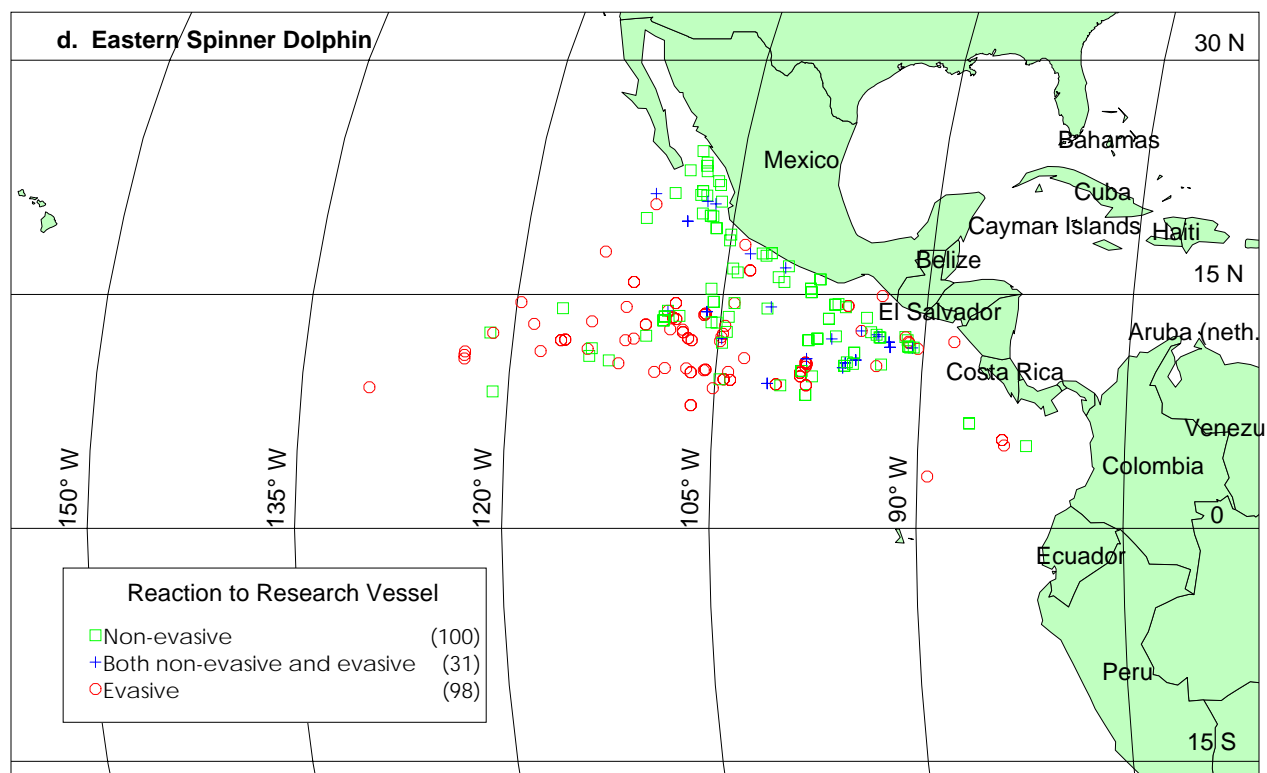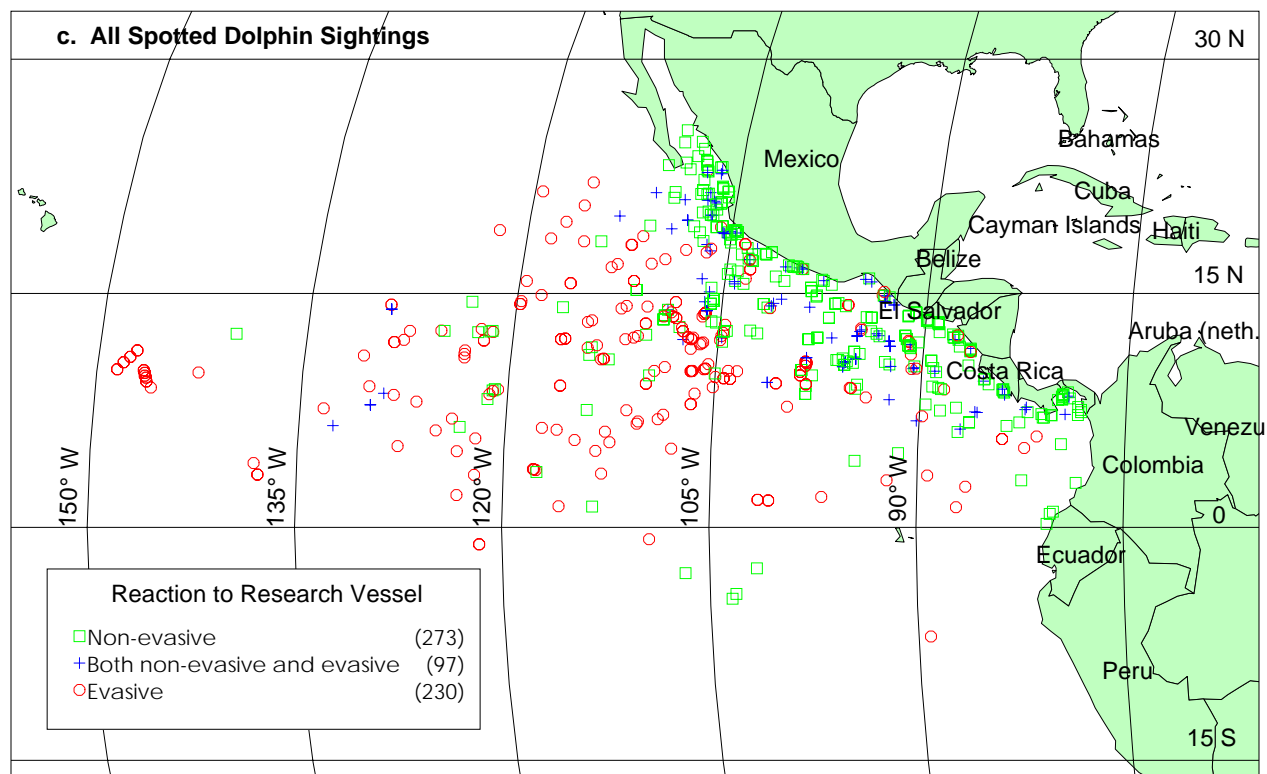sightings as "evasive" or "non-evasive."

Figure 3. Geographic plots of 1998-1999 ETP dolphin sightings, separated by behavioral reaction to the research vessel. (a) offshore spotted, (b) coastal spotted, (c) all spotteds, (d) eastern spinner, (e) short-beaked common, and (f) striped dolphins.
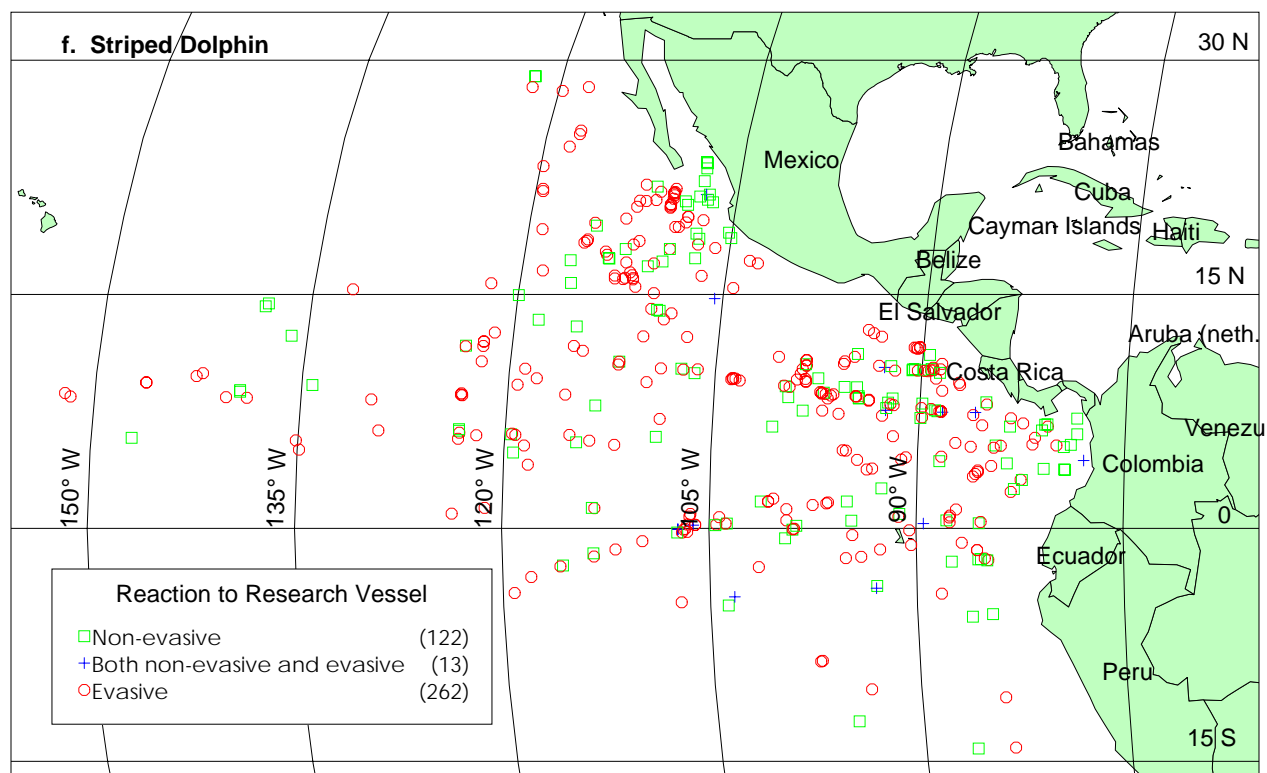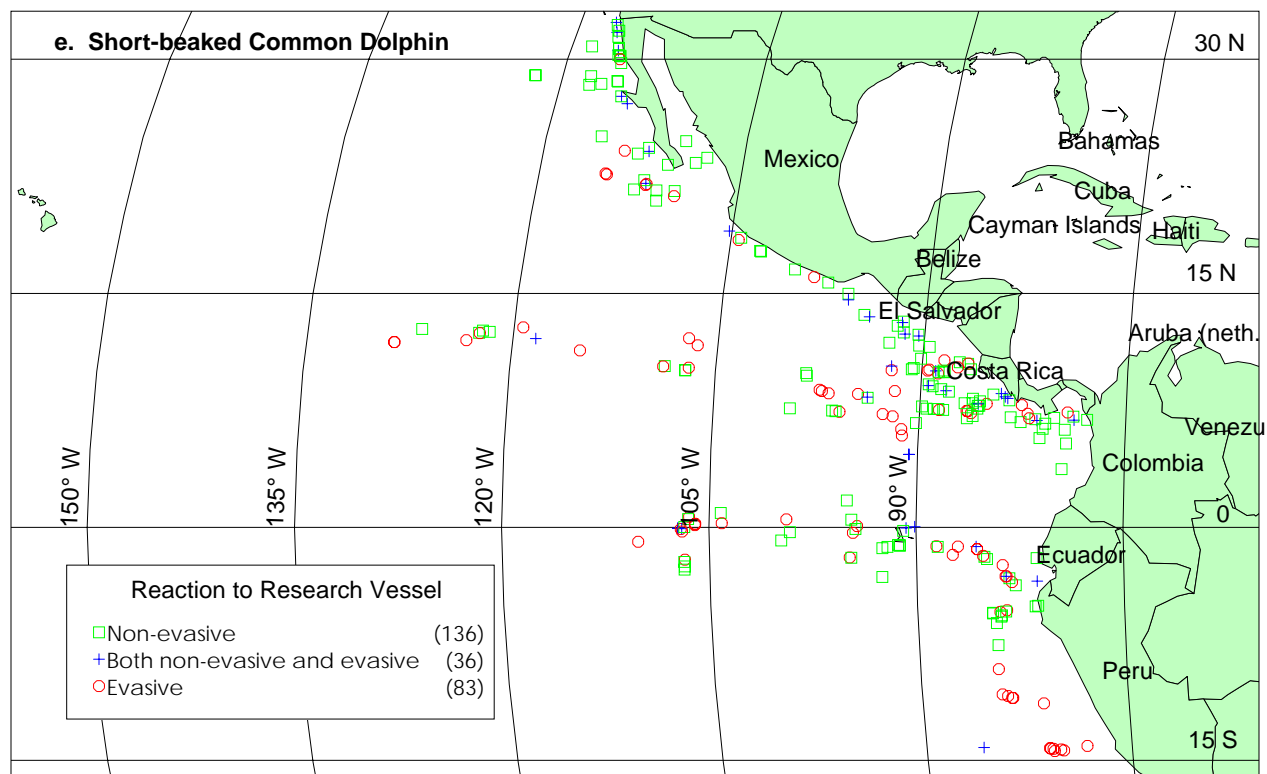
c. All Spotted Dolphin Sightings

30 N

Mexico

Bahamas

Cuba

Cayman Islands Haiti

Belize

15 N

El Salvador

Aruba (neth.

Costa Rica

Venezu

Colombia

0

Ecuador

Peru

15 S

150° W   135° W   120° W   105° W   90° W

Reaction to Research Vessel

☐ Non-evasive   (273)
+ Both non-evasive and evasive   (97)
○ Evasive   (230)

d. Eastern Spinner Dolphin

30 N

Mexico

Bahamas

Cuba

Cayman Islands Haiti

Belize

15 N

El Salvador

Aruba (neth.

Costa Rica

Venezu

Colombia

0

Ecuador

Peru

15 S

150° W   135° W   120° W   105° W   90° W

Reaction to Research Vessel

☐ Non-evasive   (100)
+ Both non-evasive and evasive   (31)
○ Evasive   (98)

e. Short-beaked Common Dolphin

Reaction to Research Vessel
□ Non-evasive   (136)
+ Both non-evasive and evasive   (36)
○ Evasive   (83)

f. Striped Dolphin

Reaction to Research Vessel
□ Non-evasive   (122)
+ Both non-evasive and evasive   (13)
○ Evasive   (262)

Figure 4. Scatter plot of RI-PCA and number of sets within 70 days and 300 nm. Lines are fitted logistic regression. Coefficients for the regression are given in parentheses. Regression iterations did not converge for coastal spotters.
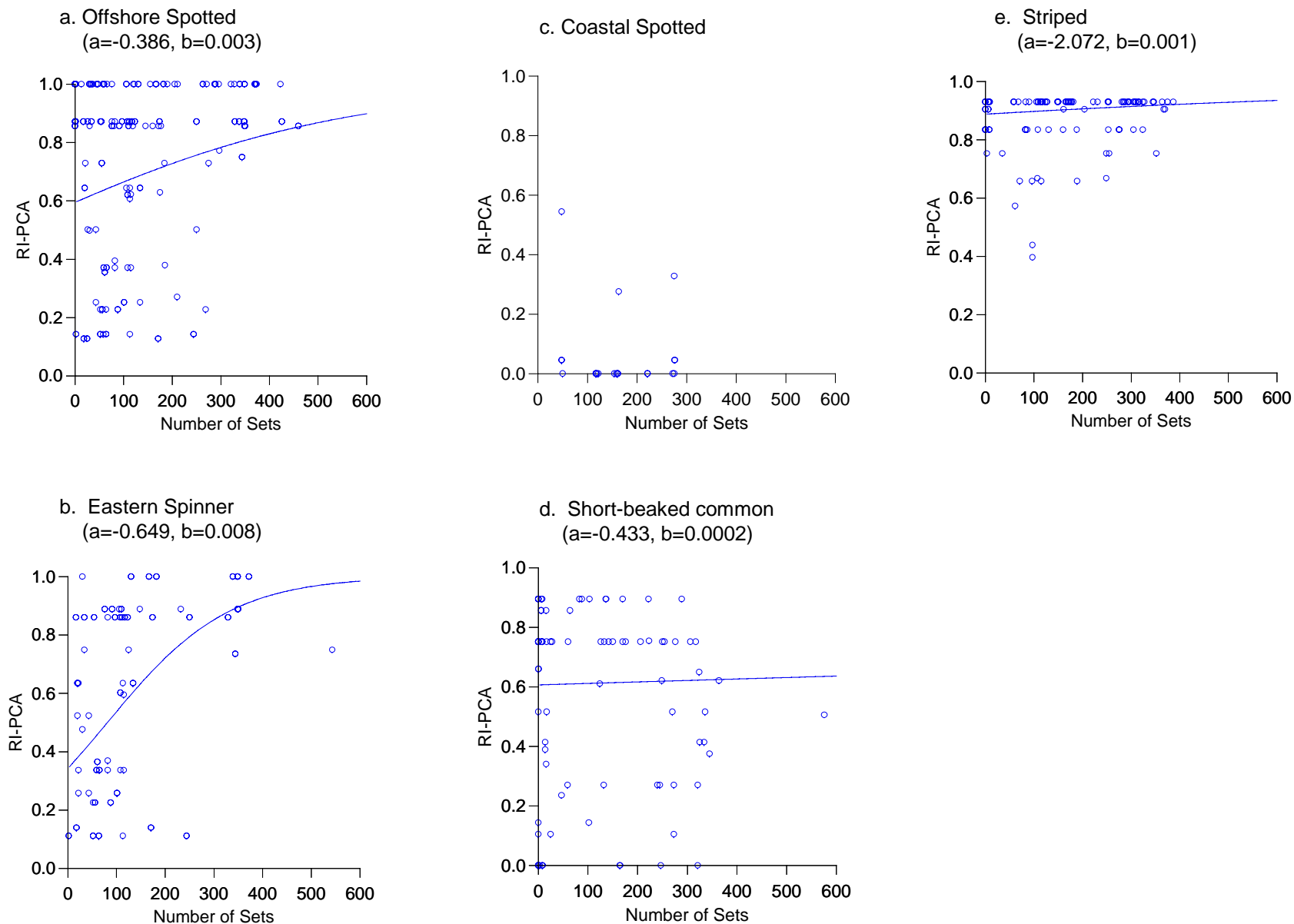
APPENDIX 1.

Guide to ETP Dolphin Behaviors Recorded on Sighting Forms

I. Group Behavior

    A. Traveling – counted when observer records "traveling," or when the individual or coordinated, polarized group is "moving" or "porpoising" in the same direction, at approximately three knots or greater. Aerial activity may also be noted.

       Can be:
      1. fast traveling – counted when observer describes rapid, directed swimming with many porpoising individuals. The school is highly polarized, or all individuals moving in the same direction.
      2. moderate traveling – counted when observer describes a few of the individuals porpoising at medium speeds.
      3. slow traveling – counted when observer describes few or no individuals porpoising at slow speeds, and/or the movement of the school is less direct and polarized.

    B. Milling – counted when observer records "milling," or describes a non-polarized school remaining in the same general area; movement of individuals is characterized by frequent changes in direction over a small spatial scale, at speeds less than 2 knots. Aerial activity may also be noted.

II. Associations

    A. Associated-swimming – counted when observer records individuals "swimming/diving," "feeding," or in a "feeding aggregation" in association with birds and/or tuna, or describes the school as moving slowly, diving deep, and spending less time at the surface; the school is not polarized. *Note: animals can be associated-swimming while traveling or milling.

III. Individual Behavior

    A. Lob tailing – counted when observer records "lob tailing," or describes one or more individuals slapping the surface of the water with the tail flukes, creating splashes.

    B. Aerial activity – counted when observer records one or more individuals "leaping," "spinning," "breaching," "tail walking," "roto-tailing," "head slapping," etc.

    C. Porpoising – counted when observer records "porpoising," or describes smooth arching leaps clear out of the water while traveling; entry into the water is splashless and rostrum first.

    D. Other – describe behavior in comments section.

IV. Behavior Relative to the Research Vessel

    A. Approach the boat – counted when observer records that individual/s are "attracted" to the boat, or alter course to swim directly towards it to "approach," but do not stay to bowride.

    B. Bow riding – counted when observer records "bow ride," or describes the individual diving and surfacing in the bow wave of the boat.

    C. Wake riding – counted when observer records "wake ride," or describes the individual diving and surfacing in the wake of the boat.

    D. Running from the boat – counted when the observer records that individuals "run from

the boat," or "up and run," or describes the animals swimming at high speeds directly away from the boat, changing direction and/or increasing speed to do so.

E. School splitting – counted when observer describes the school "splitting" or "breaking into subgroups." If recorded by the observer, the composition of the groups before and after the split is also noted. This is not applicable to animals clumped in subgroups that remain so throughout the observation.

    1. If a school splits, the individuals/subgroups can:
        a. move off in different directions (scatter) – counted when the observer records that the individuals/subgroups "scatter," or "swim away in different directions."
        b. continue to move in the same direction – counted when observer describes the individuals/subgroups swimming off together.

    2. The final composition of the subgroups can be either:
        a. mixed – different species in the same subgroup. Counted when observer records that subgroups are "mixed species."
        b. single species – subgroups are species-specific. Counted when observer records that subgroups are "single species," or "species-specific."

F. School coalescing – counted when observer describes that after initial sighting, a more scattered school (perhaps milling or associated w/birds and tuna) "coalesces," "tightens," or "closes ranks" to become more tightly aggregated, cohesive, and polarized.

G. Low swimming – counted when the observer describes the individuals as difficult to see, due to swimming "low in the water," with "only the dorsals or small patches of back" visible on the surface.

H. Other "evasive" behaviors – counted when observer records that the individuals "avoid the boat," "avoid the biopsy boats," "scatter," are "ship shy," make "frequent changes in direction," or "slink off," etc.

V. Spatial Distribution of Individuals

A. Tightly aggregated – counted when observer records that the animals are in a "tight group/formation," or describes that the school is easily discernible; the beginning and end are well defined.

B. Loosely aggregated – counted when observer records that the animals are "spread out over a wide area," or are "widely spaced," or describes that the school is difficult to discern; the beginning and end are not well defined. If animals are loosely aggregated, they can be distributed:

    1. uniformly – counted when observer records that individuals are approximately "evenly spaced."
    2. clumped – counted when the observer records the presence of "subgroups."

VI. Composition of Schools

A. The presence or absence of calves/juveniles in the school is counted when the observer records that they are visible.

B. The initial and final species composition of the school is counted if the observer records them.

APPENDIX 2

Additional Behavior Observations – Delphinids Only

Closest distance between dolphins and vessel: _____

In you estimation, when first observed,
       Were the animals already reacting to the research vessel?   Y   N   U   O

I. Group Behavior

Behavior when first observed (circle all that apply):

| fast traveling | moderate traveling | slow traveling | milling | associated swimming | unknown | other |

Did the behavior change during observation?   Y   N   U   O

If the behavior changed, what did the behavior change to?

| fast traveling | moderate traveling | slow traveling | milling | associated swimming | unknown | other |

II. School Shape

Were individuals spaced: tight   loose   unknown   other

If loose, were the individuals: uniform   clumped   unknown   other

III. School Composition

Calves present?   Y   N   U   O

IV. Reaction to the Vessel

Approach the boat?   Y   N   U   O

Bow ride?   Y   N   U   O

Run from the boat?   Y   N   U   O

Low swimming?   Y   N   U   O

Did the school split?   Y   N   U   O

If yes, did the subgroups move off in different directions?   Y   N   U   O

If it's a mixed school, was the final subgroup composition: mixed   single species   unknown   other

V. In your estimation, relative to the research vessel, was this school:

evasive   non-evasive   both   cannot be determined   other

APPENDIX 3

DOLPHIN BEHAVIOR IN THE ETP
Background and questions to think about when you write your narrative on the sighting form.
22 July 1999

We are interested in dolphin behavior at sea. Ultimately, we would like to know how the tuna fishery is affecting the behavior of ETP dolphins. However, as you can well imagine, this is an extremely difficult question to answer because there are so many factors (oceanographic, ecological, and social) contributing to observable behavior and because a tuna boat is a far cry from our research vessels. Therefore, our goal here is simply to observe and record all that we can about the behavior of ETP dolphins, and specifically, whether or not the dolphins are responding to the research vessel. This project focuses on the following four species: spinner, spotted, and common dolphins, which are involved in the tuna fishery, and in contrast striped dolphins, which are not heavily involved in the fishery.

In particular, we would like to read your observations about the following:

1. Does dolphin behavior change in response to the research vessel? Answering this entails observing the dolphins' behavior both before *and* after they detect the ship. Please note when your observations begin, relative to whether or not you suspect the dolphins have detected the ship. Please describe what the dolphins were doing initially, at what time or distance they changed their behavior in response to the ship, and what they were doing subsequently. If the dolphins were already reacting to the ship at the time they were first seen (e.g. running away from the ship, or coming in to bow ride), it is important to note this.

2. Please describe the composition and spatial organization of the dolphin school. Describe the spatial distribution of the school…are the individuals clumped or uniformly distributed? If the school is comprised of mixed species, do they swim together or separately? Please note if you see calves or juveniles, and if you can identify adult males or females. It is possible that dolphin schools containing young react differently to the vessel than schools consisting of sub-adults or adults.

3. Were the dolphins actively avoiding or not avoiding the research vessel? We admit that this is ascribing motivation to dolphin movement, something that we really cannot do. But you can describe the dolphin behaviors that created this impression for you. It is especially critical that if the dolphins don't change their behavior in response to the research vessel, we can document this lack of response. However, if the dolphins do change their behavior we need to be able to document specific dolphin behaviors that indicate whether they were "attracted" to the ship (moved toward the ship) or whether they were "avoiding" the ship (moved away or were difficult to observe). Think about how visible the dolphins were…were they difficult to see? For example, do they swim "low" or "hide" on the backside of waves? Do they run, or run towards something, such as a rain squall? Likewise, if you think that the dolphins are attracted to the ship, describe what gives you that impression. E.g. what percentage of the school comes toward the ship, how many individuals bow ride or wake ride, etc.?

4. Does the dolphin school change shape in response to the research vessel? If it does, please record when you first detect the response. Does the school coalesce or split apart? Note that schools can split and later coalesce, and vice versa. When threatened by predators, social species in open habitats (including many cetaceans) often coalesce, essentially hiding among other individuals in what is known as the "selfish herd" effect (Hamilton 1971) or more commonly as "safety in numbers." Therefore it is interesting to us that when dolphin schools encounter a research vessel, they are sometimes described as splitting. Of course, this makes good sense as a response to a purse seine because schools that are dispersed over a wide spatial area are more difficult to net. If the school splits please describe when and how it occurs. Do the dolphins split up into subgroups or scatter as individuals? Do they scatter in all directions, or split up but continue to move in the same direction? If the school was mixed, what is the species composition of the subgroups (single species or mixed species subgroups)? Sometimes a dolphin school that is initially encountered as a mixed school later may have only one species observable. Which species remains?

5. Why do dolphins and tuna school together? (The million-dollar question). Please describe anything that might help to determine what the dolphins are doing when they swim with tuna. Are they doing anything differently from when they school without tuna? Two (of many) competing hypotheses are the foraging hypothesis and the protection-from-predation hypothesis (see discussion in Scott and Cattanach 1998). Do you see any evidence of the dolphins feeding (such as an individual with a fish in its mouth)? When the research vessel approaches, what do the two species do relative to one another…do they coalesce or separate? Does one species appear to respond earlier to the research vessel than the other does?

Quantifying dolphin behavior is a difficult task. Behavior is notoriously variable and difficult to quantify reliably. However, the information we can gain by recording dolphin behavior at sea provides insights into many aspects of dolphin ecology, including perhaps the nature of their interactions with tuna boats. We greatly appreciate your support on this project. Remember, you are our eyes…please tell us what you see!

<u>Literature Cited</u>

Hamilton, W. D. 1971. Geometry for the selfish herd. Journal of Theoretical Biology 31:295-311.

Scott, M. D. and K. L. Cattanach. 1998. Diel patterns in aggregations of pelagic dolphins and tunas in the eastern Pacific. Marine Mammal Science 14(3):401-428.

For comment/questions please contact: Sarah Mesnick (sarahlyn@caliban.ucsd.edu)

Appendix 4. Responses to comments by reviewers from the Center for Independent Experts

Not all of the CIE reviewers reviewed our paper. All suggestions specific to this report were incorporated in the final report, as detailed below.

Martineau Review. Wrote that ours is a "fascinating" paper with dolphins spread over 5% of the ocean's surface trained to exhibit specific behavior due to intensive industrial effort.

DeGuise Review. Wrote that we "beautifully quantified behavior" and thought that our measure of fishing effort was appropriate.

Ortiz Review. Did not review our paper.

Janet Mann Review. Mann commented on two aspects of the paper: (1) that coastal dolphins are likely to experience higher boat traffic, but lower fishing effort, and this may confound the data and (2) that the way the behavioral data were collected may have led to biases in the recording of behavioral data, and in fact a conservative one in some cases. In response to the first point, our results are thus consistent with a specific response to the fishing effort, not to boating effort. In response to the second point, we have re-written the caveat section of the discussion to touch on each of the points raised in her review.